Title: Facile Manufacturing of ZnO Based Solar Cell Materials

ABSTRACT

Harnessing solar energy is one of the major routes to reduce the consumption of fossil fuels and abate pollution. To achieve this goal, cheaper and faster techniques for manufacturing of efficient photovoltaic cells are needed. In this thesis we show various methods for efficient production of solar cell components. The main focus of this work is rapid preparation of ZnO based solar cell components using solution based techniques and fabrication of dye-sensitized solar cells using these components. The overall scenario in this direction has been discussed in Chapter-1. In the rest of the thesis, individual chapters discuss independent but related works and the current literature on individual topics are discussed in those chapters.

The second chapter deals with preparation of aluminium-doped zinc oxide (AZO) based transparent conducting oxide films using sol-gel techniques. Usually sol-gel derived AZO films require additional post-annealing treatment under inert or reducing gas environment for better conductivity, typically resistivity in the range in the range of 10^{-2} to 10^{-4} Ω-cm. This step increases the complexity of operation and processing time could increase by 6 hours or more. In this work we have shown an efficient technique to replace this post treatment. Our technique is based on rapid cooling and gas blanketing strategy. This cooling method requires typically 5 min to improve the electrical properties. Several properties such as electrical, optical, crystalline and morphology of the films were investigated thoroughly in this work. The properties of the films, prepared using this new technique is found to be similar to those prepared using the post treatment.

The third chapter focuses on the preparation of ZnO based nanoforest like structures using microwave-assisted hydrothermal technique. Compared to conventional hydrothermal technique that requires typically 30-40 h, the proposed microwave-assisted hydrothermal technique is much faster and produces nanoforest of similar quality within 3-4 h. Microwave-assisted synthesis requires tuning of various parameters such as zinc and ammonia concentration, duration of microwave irradiation etc. which have been optimized to find out the sweet zone where the nanowire density and branching can be controlled effectively. An efficient seed deposition technique is also developed in this work for efficient branch growth. Such seeding technique

needs around 5 min instead of hour long bath deposition methods. Using these techniques, dense nanoforest of ZnO could be produced within a few hours. Morphological and crystalline properties of the nanoforest layer was studied using a battery of tests like SEM, XRD, EDS etc. which demonstrate that the microwave synthesized films are nicely crystalline material with epitaxially grown crystal faces.

The fourth chapter discusses a work where we have used the ZnO nanoforest grown using microwave-assisted synthesis for preparation of dye sensitized solar cells. Usually, the DSSC fabricated using ZnO nano-structured photoanode with ruthenium-based photosensitizer dye molecules are less efficient (1-6 %) in compared to those using TiO_2 as mesoporous layer (typically 10 %efficiency). This chapter explores the reasons for this. Usually a dilute dye-solution (typically 0.5 mM) is used for dye loading for about 1-2 hours. Using scanning electron microscopy, we show that Ru-based dye corrodes the ZnO electrode surfaces. Within a few minutes of dye soaking, such corrosions take place and this corrosion is extremely severe for ZnO nanoforest because branches and sub branches are very thin. Hence, highly concentrated dye solution (3 M) should be used with very low dye loading time (2 min) for reasonable efficiency. We study these two parameters in detail and optimize the dye loading condition for cell efficiency. The efficiency of the DSSC obtained by us is significantly higher than that reported for similar configuration (2.9 %). With optimum dye loading we could increase the current density of the cells to a great extent.